

## VII.4 Lanthanum Gallate Electrolyte Based Intermediate-Temperature Solid Oxide Fuel Cell Development

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### Objectives

- Evaluate alternative anode materials in order to reduce anode-electrolyte reactivity
- Develop tape cast process to fabricate thin electrolyte cells
- Fabricate single cells using a supported structure
- Demonstrate intermediate-temperature fuel cell operation
- Test short stacks using 10x10 cm cells

### Approach

- Modify the anode composition and verify reduction in reactivity using x-ray diffraction of reacted anode-electrolyte powder mixture
- Perform tape sintering studies to fabricate supported single cells
- Test single cells at 700-800°C for short-term and long-term performance

### Accomplishments

- Determined that the modification introduced into the nickel-based anode reduced the reactivity between nickel and lanthanum gallate
- Fabricated single cells using thin supported electrolyte with electrolyte thickness ranging from 30 to 75 microns
- Demonstrated single cell performance with an area specific resistance of 0.5 ohm-cm<sup>2</sup> at 700°C
- Demonstrated stable 1,000-hour performance at an operating temperature of 700°C

### Future Directions

- Fabricate full-size (10x10 cm) thin electrolyte cells
- Perform stack tests to verify performance and stability benefits demonstrated in single cells

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### Introduction

Reducing the operating temperature of solid oxide fuel cells (SOFCs) offers several benefits:

improvement in long-term stability by slowing physical and chemical changes in the cell materials; lower-cost systems by the use of less expensive balance-of-plant components; compatibility with

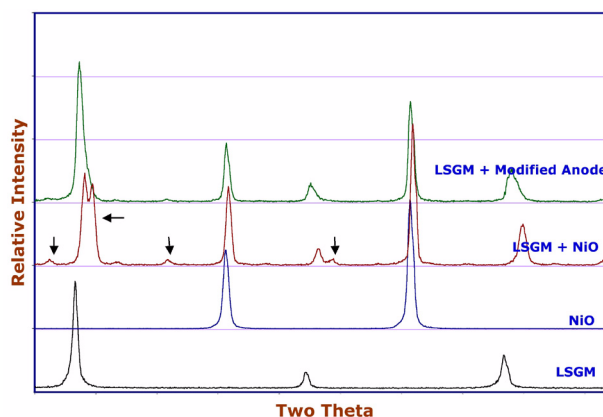
hydrocarbon reformation process allowing partial internal reformation, which in turn reduces the heat exchanger duty; and finally, the potential to improve thermal cycle capability. In addition, the use of stainless steel interconnects is also facilitated by the lower operating temperature. A temperature range of 650 to 700°C is ideally suited to derive the performance stability, system integration and cost benefits.

In order to derive the advantages of the lower operating temperature, two factors that limit the cell performance, namely the electrolyte resistance and electrode polarization, must be addressed. Lanthanum gallate compositions have shown high oxygen ion conductivity when doped with Sr and Mg. Unlike other oxygen ion conductors such as ceria and bismuth oxide, the Sr- and Mg-doped lanthanum gallate (LSGM) compositions are stable over the oxygen partial pressure range of interest. The combination of stability in fuel gas environments and high oxygen ion conductivity makes the LSGM material a potential choice for intermediate-temperature SOFCs. However, challenges in the development of electrode materials and cell fabrication processes need to be overcome to make use of the potential of the LSGM electrolyte.

### **Approach**

Nickel-based anodes have been successfully demonstrated to be catalytic for fuel oxidation in zirconia electrolyte-based SOFC systems. A modified nickel anode composition was evaluated using powder mixtures of the anode and LSGM electrolyte. The reacted powder mixture was analyzed using x-ray diffraction technique. Additionally, an 8-cell stack was tested for over 1,000 hours, and the anode-electrolyte interface was analyzed using scanning electron microscopy for evidence of nickel diffusion into the electrolyte.

Tape cast process development was performed to cast LSGM tape of various thicknesses to provide sintered electrolyte thicknesses ranging from 75 to 300 microns. The process variables included powder surface area, organic content in the tape slip, and sintering temperature. The primary objectives of the activity were to achieve sintered electrolyte density and flatness required for stacking. Single cells with



**Figure 1.** Powder X-ray of Baseline and Reacted Electrolytes, Anode Powders

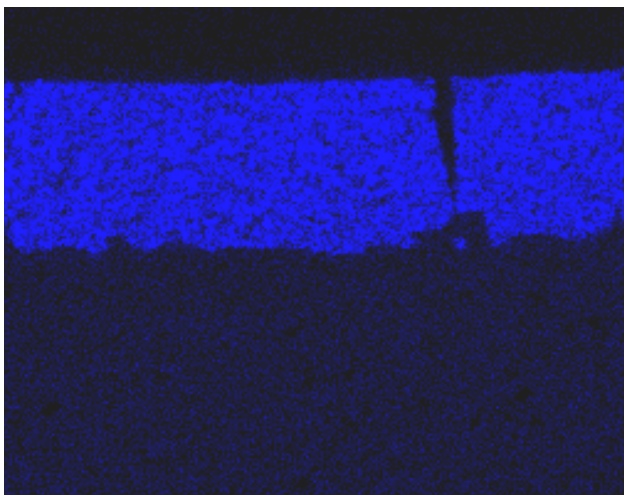
1 to 2.5 cm<sup>2</sup> active area were tested for performance characteristics and long-term stability.

### **Results**

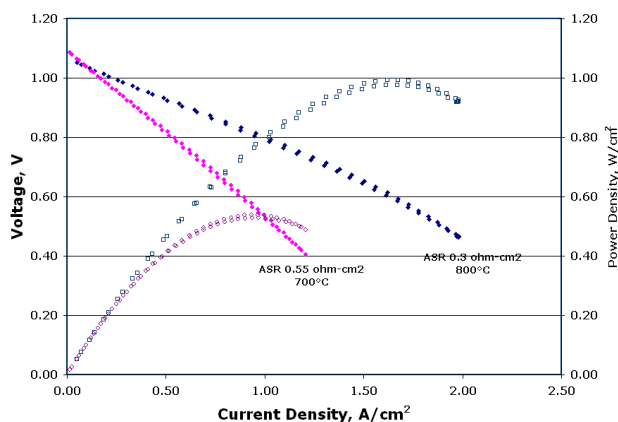
The modification to the nickel anode was found to significantly reduce the reactivity with the LSGM electrolyte. X-ray diffraction pattern for the powder mixture of the anode-electrolyte calcined at 1300°C is shown in Figure 1. Diffraction pattern for the baseline LSGM, NiO, and a mixture of the two are also shown in the figure. It can be seen that the reaction phase peaks prominent in the baseline mixture are significantly reduced in their intensities for the modified anode.

In order to verify the long-term stability of the anode-electrolyte interface, a stack was built and tested for 1200 hours. Although performance degradation was observed, attributable to chromium evaporation from the interconnect, scanning electron microscopy of the anode-electrolyte interface showed no detectable diffusion of nickel into the electrolyte, nor were any interfacial reaction products observed. The nickel x-ray map is shown in Figure 2.

Thin electrolyte single cells were fabricated using the tape lamination technique. Both anode and cathode structures were evaluated as the support for the electrolyte. The performance of a cathode-supported cell is shown in Figure 3. The thin, 75-micron LSGM electrolyte cells showed an area specific resistance of 0.5 ohm-cm<sup>2</sup> at an operating



**Figure 2.** Nickel Map of Anode-Electrolyte Interface after 1200-hr Stack Test

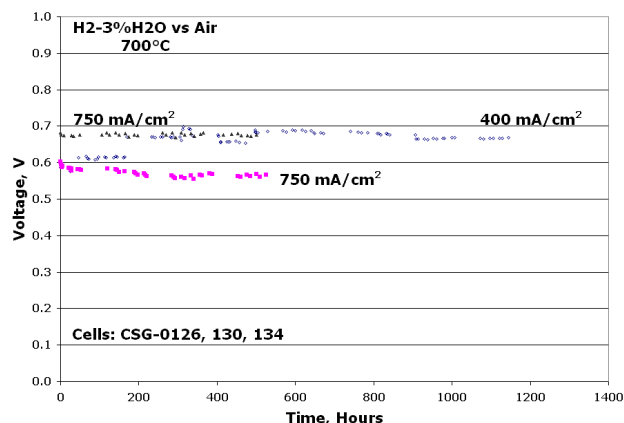


**Figure 3.** Performance of a Cathode-Supported LSGM Cell; Electrolyte Thickness of 75 Microns Was Used

temperature of 700°C. The long-term performance of selected cells is shown in Figure 4. Similar performance and stability results were also obtained using cells with the anode-support configurations. Thus, the performance benefits of using high-conductivity LSGM electrolyte and the stability improvement by using the modified anode were established in single-cell tests.

### **Conclusions**

- Sr- and Mg-doped lanthanum gallate compositions show exceptionally high oxygen ion conductivity and stability in SOFC operating



**Figure 4.** Long-term Stability of Cathode-Supported Cells at an Operating Temperature of 700°C

conditions for use at the intermediate temperatures of 650-700°C.

- The anode reactivity that is known to cause long-term instability has been addressed by introducing a modification to the nickel-based anode composition.
- A 1000-hour stack test provided additional confirmation on the effectiveness of the anode modification.
- Thin, supported cells meet the performance target of 0.5 ohm-cm<sup>2</sup> resistance at 700°C.
- Long-term tests of single cells show stable performance.

### **FY 2004 Publications/Presentations**

1. Lanthanum gallate electrolyte for intermediate temperature SOFC operation, S. Elangovan, B. Heck, S. Balagopal, D. Larsen, M. Timper and J. Hartvigsen, Presented at the International Symposium on "Solid Oxide Fuel Cell (SOFC) Materials and Technology," 28th International Cocoa Beach Conference and Exposition of the American Ceramic Society, January 25-30, 2004 at Cocoa Beach, FL.
2. Intermediate temperature stack operation using lanthanum gallate electrolyte system, S. Elangovan, B. Heck, S. Balagopal, Insoo Bay, R. Merrill, and D. Larsen, Proc. Sixth European SOFC Forum, Lucerne, Switzerland, p. 97, June 28 - July 2, 2004.